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Original Research

Pediatric Digit Replantation: A Nationwide Analysis of Failure Rate, Complications, and Potential Factors Affecting Failure

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Purpose: Function and cosmesis may be improved by replantation following digital amputation in pediatric patients. However, accurate failure and complication rate estimates may be limited as most pertinent studies reflect single center/surgeon experience and therefore are limited by small sample sizes. The primary aim of this study was to assess the rate of failure (amputation) following pediatric digital replantation. Secondary aims include evaluating the rate of complications and associated resource utilization (intensive care unit stays, readmission rate, and hospital length of stay).
Methods: Digital replantation patients were identified from 47 pediatric hospitals using the 2004 to 2020 Pediatric Health Information System nationwide database. Using applicable International Classification of Disease 9/10 and Current Procedural Terminology codes, we identified complications after replantation, including revision amputation, infection, surgical complications, medical complications, admission to intensive care unit (ICU), and length of stay.
Results: Of the 348 patients who underwent replantation the mean age was 8.3 ± 5.1 years, and 27% were female. Mean hospital length of stay was 5.8 ± 4.7 (range, 1–28) days. Of the 53% of patients who required ICU admission, the mean ICU length of stay was 2.4 ± 3.3 days. Failure/amputation after replantation occurred in 71 (20.4%) patients, at a mean of 9.7 ± 27.2 days postoperatively. Surgical complications occurred in 58 (17%) patients, 30-day hospital readmissions occurred in 5.7% of patients, and 90-day readmissions occurred in 6.3% patients.
Conclusion: The estimated rate of failure following pediatric digit replantation was 20%. Our data on failure and complication rates and associated resource utilization may be useful in counseling pediatric replantation patients and their families and provide an update on prior literature.
Level of Evidence: IV, Prognosis.

Traumatic pediatric digital amputation is a rare injury with potential devastating psychological and social outcomes.[1–3] Replantation of digits is performed more frequently in the pediatric population than in the adult population, with 20% to 40% of digits replanted in children compared to approximately 11% attempted in adult patients.[4–6] The functional outcomes of pediatric digital replantation has been reported to be quite favorable.[7–10] In addition, pediatric patients typically have less comorbidity and better healing potential than adult patients. For these reasons, indications for digital replantation are broader in pediatric patients than in the adult patient, and treatment for replanting even single digits and/or those proximal to the flexor digitorum superficialis insertion are typically undertaken.[5] Given the rare occurrence of this procedure overall, the success rate of replanted digits in the pediatric population is unclear.[11]

Previous literature has reported failure rates of pediatric replanted digits to be quite broad ranging from 3% to 53%.[8,12–18] These studies are mostly limited to a single institution with low numbers of patients included over decades of inclusion. A database study evaluated the outcomes of 455 pediatric patients with replanted digits between 1999 and 2011 and found that approximately 19% required amputation.[5] This study also noted that the

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rate of attempted pediatric digit replantation during this period was consistent and low at 27% and that short-term outcomes were generally better for pediatric patients than adult patients.

The primary purpose of our study was to evaluate failure rate, defined as a digit requiring revision amputation, of pediatric traumatic digit amputations that underwent replantation surgery. The secondary purpose of our study was to evaluate the rate of complications and associated resource utilization (readmission rate and hospital utilization). Finally, we aimed to evaluate the association of potential patient- and treatment-specific factors with the rate of failure.

Materials and Methods

This study was reviewed by our institutional review board and found to be exempt. Pediatric patients (age < 18 years) with a diagnosis of digit amputation (International Classification of Disease [ICD] 9/10) who underwent digit replantation (Current Procedural Terminology [CPT] 20816, 20822, 20824, 20827) between January 2004 and January 2022 were identified using the Pediatric Health Information System (PHIS) (Appendix 1, available online on the Journal's website at https://www.jhsgo.org).[19] The PHIS database is an administrative database that contains patient- and treatment-specific data (patient demographics, diagnosis, and procedures) and billing information. Currently, there are more than 50 participating hospitals throughout the United States. The PHIS has been used previously to evaluate the outcomes of several orthopedic procedures, including studies specific to hand surgery.[20–24] Patients from 47 of the 50 PHIS hospitals were included in our study. Only hospitals with surgical replantation data were included. The PHIS also includes Childhood Opportunity Index (COI) scores for each patient admitted to participating hospitals. COI scores are calculated at the nine digit zip code level and are based on 27 factors related to resources, such as education, health and environment, and social and economic domains.[25] The median COI in the US is 50 (range, 0–100), with a high score indicating a higher opportunity.

Exclusion criteria included any patient who underwent additional orthopedic surgeries during their initial hospital course and patients treated in the emergency department and/or ambulatory surgical center. These criteria were used to ensure a more similar patient population and eliminate confounding injuries, other than their replantation, that would keep patients in the hospital. Only patients who underwent replantation of digits were included, and patients who underwent digit revascularization were excluded to also allow for a more similar patient population and control for confounders. Codes for composite grafting were also excluded to attempt to only include patients who underwent a true replantation procedure. Patient demographics (age at procedure, sex, race) were collected and tabulated. All additional procedural and diagnostic codes, hospital readmissions, and emergency department visits from date of surgery to study initiation for each patient were collected. Replanted digit failure was defined as essentially a vascular failure or any digit that required revision amputation (CPT 25929, 26910, 26951, and 26952) during or any time after replantation surgery. Digits that survived or were vascularized, but were considered a 'functional failure' due to issues, such as stiffness, were not reported. Of note, only digits that were also billed for revision amputation codes were included as "failures." Digits that were allowed to autoamputate or heal secondarily on their own were not able to be reported. Only additional procedures performed within these 47 hospitals were able to be accounted for. If the patient underwent a procedure at an ambulatory surgery center and the coding for this procedure was not included, the patient was not included in the database.

Table 1
Patient Demographics

Characteristics	Mean (N)	SD (%)
Age, y	8.3	5.1
Sex		
Female	95	27%
Male	253	73%
Race/Ethnicity		
White	239	68%
Hispanic	48	14%
Black	25	7%
Other	27	8%
Childhood Opportunity Index	48.8	28.2
Payer		
Private	193	55%
Government (Medicaid)	129	37%
Self-pay	25	7%
Missing	1	0.3%
Operative Digit Type		
Finger	259	74%
Thumb	77	22%
Both finger and thumb	12	3%
Length of Stay, days	5.8	4.7
Intensive Care Unit Admission	184	53%

Infection, medical and surgical complication codes included in the PHIS database were also collected for each patient and grouped into subcategories. The PHIS database includes over 6,000 different ICD codes indicative of complications. Such codes were gathered for each patient.

Continuous patient- and treatment-specific variables were summarized as mean (standard deviation [SD]), median (interquartile range [IQR]), and range. Categorical variables were summarized as N (%). The overall failure rate was calculated as percentage of the total. Infection, same visit surgical complications, and other medical and surgical complications that are kept within the PHIS database were tabulated. Finally, univariate and multivariate binary logistic regressions were used to determine the association of patient- and treatment-specific factors with the likelihood of a replanted digit to fail.

Results

A total of 348 patients met inclusion criteria from the 50 hospitals included in our study. The average age was 8.3 ± 5.1 years, and the cohort included 27% female. The average COI score was 48.8 ± 28.2. The average hospital length of stay was 5.8 ± 4.7 days. Of these patients, 53% (N = 184) required intensive care unit (ICU) admission for an average length of ICU stay of 2.4 ± 3.3 days. Of the 348 patients with replantations, the thumb was exclusively replanted in 22.1% (N = 77), a nonthumb digit was exclusively replanted in 74.4% (N = 259), and 3.4% (N = 12) of patients had both a thumb and an additional finger replanted. Additional patient demographics are included in Table 1.

Of the 348 patients, failure/amputation after replantation occurred in 20.4% (N = 71) of patients, which occurred at a mean of 9.7 ± 27.2 days (IQR, 0–9) postoperatively. These 71 patients returned to the operative suite on a separate day for revision amputation of their replanted digit. Surgical complications occurred in 16.7% (N = 58) of patients. Hospital readmission occurred in 5.7% (N = 20) of patients within the first 30 days postoperatively and in 6.3% (N = 22) of patients within the first 90 days postoperatively. However, we were unable to determine whether all readmissions were associated with the index replantation surgery given the nature of this study. During the 2004–2022 study period, we were able to capture secondary operations and complications that occurred in patients within the

Table 2
Complications

Complication	N (total 348 patients)	%
Revision Amputation	71	20.4%
Infection	14	4%
Other	9	3%
Head/neck and respiratory	5	1%
Postoperative-related complications	2	1%
Surgical Complications	58	16.7%
Digit-related complications*	41	12%
Bleeding-related complications	9	3%
Cardiac and respiratory complications	7	2%
Other	7	2%
Medical Complications	2	0.6%
Drug allergy	1	0%
Unspecified complication of medical care	1	0%

* Necrosis, infection, etc.

PHIS hospital that their index surgery was performed. Additional complications are reported in Table 2 and Appendix 2 (available online on the Journal's website at https://www.jhsgo.org).

Univariate analysis demonstrated that replantation of the thumb compared to finger was associated with decreased likelihood of requiring revision amputation (odds ratio [OR], 0.42; 95% confidence interval [CI] 0.23−0.77; $P = .006$), whereas replantation of a thumb and a nonthumb digit(s) was associated with increased failure rates (OR, 5.18; 95% CI: 1.37−19.60; $P = .015$). Patients with government insurance and those who self-paid were also more likely to require revision amputation than patients with private insurance with ORs of 1.95 (95% CI, 1.21−3.13; $P = .006$) and 2.94 (95% CI, 1.26−6.85; $P = .013$), respectively. All other univariate analyses were not significant (Table 3).

Multivariate analysis demonstrated patients who self-pay or had government insurance were also more likely to require revision amputation than patients with private insurance with ORs of 3.94 (95% CI, 1.60−9.69; $P = .003$) and 2.36 (95% CI, 1.37−4.05; $P = .002$), respectively. Patients who had both a thumb and other finger replanted had a higher odds of failure, whereas patient age, race, COI scores, length of stay, ICU admission, and patient sex were not statistically significant predictors of failure rate (Table 4).

Discussion

The main finding of our study was that the failure rate of pediatric digit replantation was 20%. The previous literature has indicated that the failure rate of pediatric digit replantation ranges from 3% to 53%.[8,12−17,26] These studies have limited sample sizes, and the results are commonly limited to one surgeon or institution. Two recent administrative studies published by Berlin et al[5] and Li et al[27] reported revision amputation rates following digit replantation of 19% and 20%, respectively, in their pediatric patients. These findings are consistent with our findings of 20% reported in our study. The current study appears to be one of the most recent database analyses evaluating the failure rate and complications of pediatric replantations. When combined with the two studies mentioned above by Li et al[27] and Berlin et al,[5] there appears to be a relatively unchanged and consistent failure rate in this realm based on the cumulation of findings from over 22 years of database monitoring. The adult population has failure rates that are slightly higher than that noted in the pediatric population (as above), with rates varying in two large adult studies between 30% to 40%.[28,29] This may in part be due to adult comorbidities, the healing potential of children, mechanisms of injury, or the willingness of an adult to cease additional aggressive intervention to save a digit.

Secondary findings of our study include relatively low complication rates. This is consistent with previous administrative database studies that have demonstrated low complication rates (10% to 13%) of pediatric digit replantation.[5,27] Despite rates being relatively low overall, it is worth mentioning given rates of complications following studies demonstrating that revision amputation rates are lower than replantation rates, and this information is pertinent to preoperative family and patient counseling.[27]

Interestingly, patients in the current study who self-pay or had government insurance had a statistically higher likelihood of replantation failure, independent of the COI, and this could indicate higher failure in more socially deprived patients. One reason for this could be that there were other barriers to accessing care or delayed presentation in these patients; however, available data do not allow for such conclusions to be drawn. This finding, however, was dissimilar from that noted in the study by Li et al[27] who found no difference based on insurance status; thus, it is difficult to draw conclusions as such.[27] In terms of other particular social determinants of health, such as race and COI, our study found no significant influence on failure of replanted digits. This may be due to the fact that failure is more likely influenced by other factors, which can also include the injury itself and perioperative and surgical care received while in the hospital.

Some literature has reported on mean hospital and ICU length of stay for patients undergoing digit replantation. Prior work has presented this as a binary finding, such as length of stay < 5 days or > 5 days. Berlin et al[5] demonstrated that 36% of pediatric patients had a hospital length of stay of > 5 days, indicating most leave the hospital before then. However, limited data on average time in the ICU are available. The current study found an average hospital length of stay of 5.8 days and an average ICU length of stay of 2.4 days for patients requiring higher level of care. Patients who were admitted to the ICU for care did not have better replant survival rates. This may be due to patients with more severe injury or tenuous replants being admitted to the ICU; however, this conclusion cannot be drawn from available data. Of the digits that failed, the mean time to failure was 9.7 days ± 27.2 days. Given the relatively longer times to failure in these patients, we would assume some of these patients had planned revision amputation surgery in the outpatient setting after discharge, but this claim needs to be validated.

Our study has several limitations that should be reported. Given that our study used an administrative database, we were unable to perform chart reviews of operative procedures, progress, and follow-up notes to obtain a more detailed analysis of surgical and postoperative complications and outcomes. The complication rates of our study were consistent with previous administrative studies but differ from studies conducted within a single institution that report higher complication rates ranging from 60% to 70%.[5,17,27] Although the database was able to identify whether a thumb or a nonthumb digit was involved, we were unable to determine the exact number of digits that were replanted or the exact number of failed digit replantations. It is likely that an increased number of digits replanted would be associated with an increased likelihood of failure. Additionally, some composite graft techniques may have been billed as a replantation, but we were unable to control for this factor. Given our study design, we were also unable to obtain information regarding functional or clinical outcomes or access radiographic images. Although using the PHIS database made our study subject to several limitations inherent to database studies, it did offer several noteworthy strengths. Given the inclusion of 47 hospitals, it is less likely that patients would be lost to follow-up if they moved to a new location near a major pediatric hospital.

Table 3
Univariate Analysis of Factors Effect on Failure Rate

Variable	Odds Ratio	95% Confidence Interval	Coefficient	Coefficient Standard Error	*P* Value
Age	1.00	0.96–1.05	0.0009	0.0224	.969
Sex					
Male	Reference	-	-	-	-
Female	1.03	0.63–1.69	0.027	0.253	.915
Race					
White	Reference	-	-	-	-
Black	0.76	0.30–1.89	−0.276	0.4669	.553
Hispanic	0.80	0.41–1.6	−0.219	0.346	.526
Other	1.75	0.86–3.54	0.557	0.361	.123
Insurance					
Private	Reference	-	-	-	-
Government	1.95	1.21–3.13	0.669	0.241	.006
Self-pay	2.94	1.26–6.85	1.078	0.432	.013
Operative Digit Type					
Finger	Reference	-	-	-	-
Thumb	0.42	0.23–0.77	1.645	0.679	.006
Both	5.18	1.37–19.60	−0.873	0.315	.015
Length of Stay	0.96	88.4–1.05	−0.04	0.04	.368
Intensive Care Unit Admission					
No	Reference	-	-	-	-
Yes	1.17	0.75–1.83	0.158	0.227	.486
Child Opportunity Index	0.97	0.89–1.04	−0.00322	0.00403	.424

Table 4
Multivariate Analysis of Factors Effect on Failure Rate

Variable	Odds Ratio	95% Confidence Interval	Coefficient	Coefficient Standard Error	*P* Value
Age	1.01	0.96–1.06	0.0116	0.025	.642
Sex					
Male	Reference	-	-	-	-
Female	1.0	0.57–1.75	−0.00	0.286	1.0
Race					
White	Reference	-	-	-	-
Black	0.59	0.23–1.728	−0.466	0.515	.37
Hispanic	0.63	0.26–1.158	−0.600	0.377	.11
Other	1.28	0.54–3.03	0.245	0.4404	.580
Insurance					
Private	Reference	-	-	-	-
Government	2.36	1.37–4.05	0.858	0.3276	.002
Self-pay	3.94	1.60–9.69	1.379	0.459	.003
Operative Digit Type					
Finger	Reference	-	-	-	-
Thumb	0.42	0.22–0.80	−0.879	0.334	.035
Both	4.7	1.11–19.52	−1.539	731	.009
Length of Stay	1.02	0.96–1.08	0.0161	0.03048	.60
Intensive Care Unit Admission					
No	Reference	-	-	-	-
Yes	1.02	0.96–1.08	0.072	0.276	.795
Child Opportunity Index	1.0	0.99–1.01	−0.002	0.005	.619

The database also allowed us to study a large number of pediatric traumatic amputations that would otherwise have been impossible at a single institution given the rare nature of this injury and operation. Further, this is a different database from other databases reporting on pediatric digital replantations in the literature. This allows for comparisons to be made regarding the consistency of results from database analyses on this topic. Additionally, this study is an update to previously published database studies in this arena, which have typically included data up to 2012.[5,27]

Finally, our study demonstrated that the failure rate of digit replantation in the pediatric population remains low (20%). We likewise found low medical and surgical complication rates and present a mean length of stay for pediatric digit replantation patients. These factors aid surgeons in shared decision making and expectation counseling when discussing treatment options for pediatric patients with traumatic digit amputations.

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